



The IMAGE spacecraft (shown as the 'star' in the figure) contains an instrument called the Radio Plasma Imager (RPI). This instrument sends out a powerful pulse of radio energy (the fish hook-shaped lines) at frequencies from 3,000 to 3 million cycles per second (Hertz). When the echos from these pulses are later received by the instrument, they can be analyzed to find the location and density of the plasma that reflected them.

Clouds of plasma in space have an interesting property: When radio waves reflect off of them, the radio frequency of the reflected signal depends on the density of the cloud! The formula that relates the reflection frequency,  $F$ , to the density,  $N$ , is given by

$$F = 9000 \times (N)^{1/2}$$

The unit of frequency is Hertz (cycles per second) and the unit for the density of the cloud is electrons per cubic centimeter.

In this problem, you will use some of the same methods and equations that IMAGE scientists use, to study the properties of plasma clouds near Earth. Although the properties of these clouds, and their locations, have been 'made-up' for this problem, your analysis of them will be similar to the methods employed by IMAGE scientists using real data.

With the formula above, solve for the density,  $N$ , and complete the table entries below.

Location	Direction (degrees)	Distance in Earth Radii (Re)	Reflection Frequency (Hertz)	Density (electrons per cc)
1	300	1.0	284,000	995
2	315	2.5	201,000	
3	350	6.5	12,600	
4	45	4.5	20,100	
5	60	3.9	25,500	
6	90	4.1	28,500	
7	120	4.0	25,500	
8	135	5.5	20,100	
9	215	7.2	12,600	
10	230	3.5	220,000	
11	270	1.2	348,000	

The equation solved for N is:

$$N = (F/9000)^2$$

Lets' calculate the answer for N for the first location in Line one of the table. Divide the reflection frequency in Column 4 by 9,000. For example, at Location 1,  $284,000/9,000 = 31.55$ . Find the square of this number:  $31.55 \times 31.55 = 995.4$ . Round this number to the nearest whole number, therefore the density of the cloud, N, at Location 1 is 995 electrons per cubic centimeter. Students will enter this answer in Column 5.

Complete the rest of the entries to Column 5 in similar fashion.

Location	Direction (degrees)	Distance in Earth Radii (Re)	Reflection Frequency (Hertz)	Density (electrons per cc)
1	300	1.0	284,000	995
2	315	2.5	201,000	498
3	350	6.5	12,600	2
4	45	4.5	20,100	5
5	60	3.9	25,500	8
6	90	4.1	28,500	10
7	120	4.0	25,500	8
8	135	5.5	20,100	5
9	215	7.2	12,600	2
10	230	3.5	220,000	597
11	270	1.2	348,000	1495

For extra credit, students can use a protractor, compass and a 4-quadrant graph paper with axis marked in intervals of 1.0 Re, to plot each of the 11 points. A red and blue crayon can be used to code each point as a high-density region (red = 400 to 1500 electrons/cc) or a low-density region (blue = 1 to 10 electrons/cc).

The low-density regions are farther from Earth and represent the plasma, which fills Earth magnetic field. The high-density regions is closer to Earth and the satellite, and corresponds to the plasmasphere region of the upper atmosphere.